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relating to

ACQUISITION OF A CODE MODULATED SIGNAL

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ACQUISITION OF A CODE MODULATED SIGNAL

5   FIELD OF THE INVENTION

The invention relates to an apparatus supporting an
acquisition of a received code modulated signal by
determining the correlation between the received code
10   modulated signal and an available replica code sequence
at different code phases relative to each other. The
invention relates equally to a system and to a method
supporting such an acquisition of a received code
modulated signal.
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BACKGROUND OF THE INVENTION

A code modulated signal has to be acquired for example in
CDMA (Code Division Multiple Access) spread spectrum
20   communications.

For a spread spectrum communication in its basic form, a
data sequence is used by a transmitting unit to modulate
a sinusoidal carrier and then the bandwidth of the
25   resulting signal is spread to a much larger value. For
spreading the bandwidth, the single-frequency carrier can
be multiplied for example by a high-rate binary pseudo-
random noise (PRN) code sequence comprising values of -1
and 1, which code sequence is known to a receiver. Thus,
30   the signal that is transmitted includes a data component,
a PRN component, and a sinusoidal carrier component. A
PRN code period comprises typically 1023 chips, the term
chips being used to designate the bits of the code

conveyed by the transmitted signal, as opposed to the
bits of the data sequence.

A well known system which is based on the evaluation of
5   such code modulated signals is GPS (Global Positioning
System). In GPS, code modulated signals are transmitted
by several satellites that orbit the earth and received
by GPS receivers of which the current position is to be
determined. Each of the satellites transmits two
10   microwave carrier signals. One of these carrier signals
L1 is employed for carrying a navigation message and code
signals of a standard positioning service (SPS). The L1
carrier signal is modulated by each satellite with a
different C/A (Coarse Acquisition) Code known at the
15   receivers. Thus, different channels are obtained for the
transmission by the different satellites. The C/A code,
which is spreading the spectrum over a 1 MHz bandwidth,
is repeated every 1023 chips, the epoch of the code being
1 ms. The carrier frequency of the L1 signal is further
20   modulated with the navigation information at a bit rate
of 50 bit/s. The navigation information, which
constitutes a data sequence, can be evaluated for example
for determining the position of the respective receiver.

25   A receiver receiving a code modulated signal has to have
access to a synchronized replica of the employed
modulation code, in order to be able to de-spread the
data sequence of the signal. More specifically, a
synchronization has to be performed between the received
30   code modulated signal and an available replica code
sequence. Usually, an initial synchronization called
acquisition is followed by a fine synchronization called
tracking. In both synchronization scenarios, a correlator
is used to find the best match between the replica code

sequence and the received signal and thus to find their relative shift called code phase. The match can be determined for example with chip accuracy. If an accuracy of a fraction of a chip is needed, the chip can be

5 presented by several samples after an analog-to-digital conversion.

During the acquisition, the phase of the received signal relative to the available replica code sequence can have

10 any possible value due to uncertainties in the position of the satellite and the time of transmission of the received signal.

Moreover, an additional frequency modulation of the

15 received signal may occur, which can be as large as +/-6 kHz, for example due to a Doppler effect and/or a receiver clock inaccuracy. The search of the code phase is therefore usually performed with different assumptions on an additional frequency modulation. For a sensitivity

20 increase, a receiver normally uses long integrations that require the frequency uncertainty to be as small as a few Hz. Therefore, even with the aligned code, a large number of frequency assumptions should be checked.

25 The initial acquisition is thus a two-dimensional search in code phase and frequency. To meet the real time processing and weak signal sensitivity requirements, usually, a massive correlator bank which is able to check in parallel hundreds and thousands of options is employed

30 for implementing the acquisition stage of a receiver.

Each correlator of such a massive correlator bank checks simultaneously another option defined by a specific code phase and a specific frequency of modulation. To this

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end, each correlator multiplies a received code modulated signal to a predetermined compensating sinusoidal signal, aligns the compensated code modulated signal with the replica code sequence at a predetermined code-phase,

5 multiplies the samples of the compensated code modulated signal and the samples of the replica code sequence element by element and integrates the multiplication results. The integration can be either purely coherent or include a non-coherent stage. In a non-coherent stage,

10 consecutive coherent integration results for a certain number of multiplication results, respectively, are further integrated by summing the absolute or the squared values of these integration results.

15 If the assumptions on the code-phase and the frequency modulation belonging to one option are correct for the received code modulated signal, then the correlation results in a larger integration value than in the case of a misalignment or an inappropriate compensation of a

20 frequency modulation. Thus, detecting the correlation peak and comparing it with a certain threshold allows to find the correct code phase and the correct frequency of modulation.

25 A massive correlator bank has the advantage that it is much faster than a sequential search correlator bank, in which the number of correlators is restricted and in which each correlator searches only one candidate at a time. It is a disadvantage of a massive correlator bank,

30 however, that its complexity is significant, if a correlation value is determined for all desired options.

SUMMARY OF THE INVENTION

It is an object of the invention to reduce the complexity
of massive acquisition engines used for the acquisition
of code modulated signals, for example of massive
correlator banks.

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An apparatus supporting an acquisition of a received code
modulated signal by determining the correlation between
the received code modulated signal and an available
replica code sequence at different code phases relative
10   to each other is proposed. The proposed apparatus
comprises a first acquisition engine for selecting code
phases which are good candidates for being the code phase
at which a received code modulated signal and an
available replica code sequence have the highest
15   correlation, and for outputting information on each
selected code phase. The proposed apparatus further
comprises a second acquisition engine for receiving
information on selected code phases from the first
acquisition engine and for performing a refined
20   comparison between a received code modulated signal and
an available replica code sequence for each selected code
phase on which information is received. The acquisition
engines can be in particular, though not exclusively,
correlator banks.

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Further, a system is proposed which comprises the
proposed apparatus and in addition a network. The
apparatus and the network are able to exchange data
between each other. The exchanged data can be used for
30   supporting the acquisition in various ways.

Finally, a method for supporting an acquisition of a
received code modulated signal by determining the
correlation between the received code modulated signal

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and an available replica code sequence at different code phases relative to each other is proposed. The proposed method comprises a first step of selecting code phases which are good candidates for being the code phase at

5   which a received code modulated signal and an available replica code sequence have the highest correlation. The proposed method comprises as a second step performing a refined comparison between the received code modulated signal and the available replica code sequence for each

10   of the selected code phases.

The invention proceeds from the consideration that for a large fraction of search options, a decision can be made with little effort, for example after a short integration

15   length in a cross-correlation. A conventional massive correlator bank will continue nevertheless checking all search options with the entire operation cycle, thus performing unnecessary computations. It is therefore proposed to distribute the calculation resources required

20   for the acquisition of a code modulated signal to two separate acquisition engines.

A first acquisition engine carries out only a preliminary search for all possible options. It does not make a firm

25   decision at each operation cycle but uses for instance a reduced operation cycle for sorting out a large amount of improbable options and for providing several remaining possible options. The duration of such a reduced operation cycle can be fixed or be defined by the

30   operational conditions. The preliminary search can be stopped for example, as soon as a decision can be made for most of the search options. The first acquisition engine can be for example a modified massive correlator bank performing many preliminary searches in parallel.

The first acquisition engine then transfers the task to check the remaining search options in more detail to a second acquisition engine. The second acquisition engine

5   can be a small engine using pipe-lining, for example a modified tracking unit. Thereupon, the first acquisition engine is free to check other possible options in a preliminary way.

10   It is an advantage of the invention that it allows to reduce the complexity of massive acquisition engines used for the acquisition of code modulated signal, and thereby for example the gate count and the area of a massive correlator bank used conventionally as acquisition

15   engine.

Alternatively, the invention allows to accelerate the processing without increasing the complexity of the acquisition engine and to reduce, for example, the delays

20   in position calculations. For instance, the time to first fix (TTFF) of a position can be reduced to one half or less.

It is further an advantage of the invention that due to

25   the structural separation, the two acquisition engines may use different algorithms and different integration length in order to optimize the processing at each stage.

In some cases, in which assistance is available, for

30   example from some network, it is also possible to use only the second acquisition engine and to keep the first acquisition engine off. Thereby, the power consumption can be reduced in certain assistance applications.

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The acquisition engines can be implemented in particular in hardware, while any supplementary processing can be implemented in hardware and/or software. Such supplementary processing can be performed for example by
5   a digital signal processor (DSP) or some other processing unit.

The invention can be employed in particular, though not exclusively, for CDMA spread spectrum transmissions, for
10   instance for a receiver of a positioning system like GPS or Galileo. The proposed apparatus can be for example such a receiver or a device comprising such a receiver, for instance a mobile terminal. In the latter case, part of the processing can be carried out outside of the
15   receiver, for example in the mobile terminal or in a network to which the mobile terminal transmits the required information.

Other objects and features of the present invention will
20   become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which
25   reference should be made to the appended claims. It should be further understood that the drawings are not drawn to scale and that they are merely intended to conceptually illustrate the structures and procedures described herein.
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BRIEF DESCRIPTION OF THE FIGURES

Fig. 1   schematically shows a system in which the invention can be employed;

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Fig. 2   is a schematic block diagram of a combination of
          a massive correlation bank and a supplementary
          correlation bank employed in an embodiment of the
          invention;

5   Fig. 3   is a flow chart illustrating the operation of the
          correlation banks of figure 2;

    Fig. 4   is a schematic block diagram of a first
          embodiment of the supplementary correlation bank
          employed in the structure of figure 2;

10 Fig. 5   is a flow chart illustrating the operation of the
          supplementary correlation bank of figure 4;

    Fig. 6   is a schematic block diagram of a second
          embodiment of the supplementary correlation bank
          employed in the structure of figure 2; and

15 Fig. 7   is a flow chart illustrating the operation of the
          supplementary correlation bank of figure 6;

    Fig. 8   is a schematic block diagram of a third
          embodiment of the supplementary correlation bank
          employed in the structure of figure 2, which is
20   cooperating with a DSP; and

    Fig. 9   is a flow chart illustrating the operation of the
          supplementary correlation bank of figure 8.

DETAILED DESCRIPTION OF THE INVENTION
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Figure 1 schematically presents a system 10 in which the
invention can be implemented.

The system comprises a mobile terminal 11 including a GPS
30 receiver 12 and a mobile communication network 16. The
GPS receiver 12 includes a receiving portion 13 for
receiving code modulated signals from GPS satellites 19,
an acquisition portion 14 for acquiring a received code
modulated signal, and a digital signal processor (DSP) 15

supporting the acquisition. The mobile communication network 16 may provide assistance data to the acquisition portion 14 using a regular radio-based communication between the mobile terminal 11 and the mobile

5 communication network 16. Alternatively or in addition, the mobile communication network 16 may perform computations for supporting the acquisition of a code modulated signal received by the GPS receiver 12 using a regular radio-based communication between the mobile

10 terminal 11 and the mobile communication network 16.

Figure 2 presents the general structure of the acquisition portion 14 of the GPS receiver 12 of figure 1.

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The acquisition portion 14 comprises a massive correlator bank MCB 21 and a supplementary correlator bank SCB 22. The receiving portion 13 of the GPS receiver 12 is connected to both correlator banks 21, 22. The massive

20 correlator bank 21 is further connected with several lines to the supplementary correlator bank 22.

Figure 3 is a flow-chart illustrating the operation of the acquisition portion 14 of figures 1 and 2.

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The massive correlator bank 21 receives from the receiving portion 13 samples of a received code modulated signal and performs a cross-correlation between the received code modulated signal and a replica code

30 sequence with a reduced integration length.

To this end, a correlator of the massive correlator bank 21 multiplies the input samples to a sinusoidal signal for compensating a possible modulation with a selected

frequency. The massive correlator bank 21 then aligns the resulting samples with an available replica code sequence at a selected code phase and multiplies predetermined ones of the frequency compensated samples, for example
5   the first ones of the samples, element by element with the respectively aligned sample of the replica code sequence. The number of the predetermined samples is significantly smaller than the number of all samples of the received code modulated signal which are overlapping
10 with the samples of the aligned replica code sequence. It is to be noted that the order of the two different multiplication operations can also be reversed. The multiplication results are integrated coherently, the integration result constituting a first indication of the
15 amount of correlation.

Alternatively, a non-coherent integration could be used. In this case, the multiplication results originating from sections of the received code modulated signal of equal
20 size are integrated separately for each section in a coherent integration. The results of these subcorrelations are multiplied with a shifted, conjugated version of themselves. In a final step, the results of these second multiplications are integrated in a non-
25 coherent integration. Thereby, residual sinusoidal modulations in the raw data, in particular from a Doppler frequency, are reduced.

In either case, the correlation is based on a shorter
30 operation cycle than in correlators of a conventional massive correlator bank.

The massive correlator bank 21 then selects a new set of
a frequency and a code-phase, and the correlator
continues with the correlation based on this new set.

5   At the same time, the massive correlator bank 21 checks
whether the last integration result indicates that the
last assumed frequency modulation and the last employed
code-phase could be the correct set of frequency and
code-phase and constitutes thus a search option for a
10 refined search. The checking may comprise for example
comparing the integration result with a threshold value.

If the set of frequency and code-phase constitute a
search option, an indication of the associated frequency
15 f_i and the associated code-phase τ_i is provided to the
supplementary correlator bank 22 using one of the
connecting lines. In addition, the associated integration
result S_i is either equally provided to the supplementary
correlator bank 22 or to a processing unit, for example
20 to the DSP 15 of the GPS receiver 12. The latter
alternative is indicated in figure 2 by an arrow with a
dashed line. The index i is used for identifying the
respective option.

25 The supplementary correlator bank 22 assigns one of its
correlators to continue the processing with the received
parameters f_i, τ_i and possibly the parameter S_i, in order
to allow a determination of the code phase and the
compensation frequency resulting in the best match
30 between the received code modulated signal and the
replica code sequence. The final determination is carried
out in a processing unit, for example the DSP 15 of the
GPS receiver 12.

The number of the correlators in the supplementary
correlator bank 22 can be sufficiently large for
processing all search options which may be output by the
5   massive correlator bank 21 in parallel. Alternatively, a
quality indication may be assigned to each search option.
In case none of the correlators of the supplementary
correlator bank 22 is free when a new search option is
output by the massive correlator bank 21, the quality
10   indication associated to the current search option is
compared to a quality indication which was associated to
previous search options now occupying the correlators of
the supplementary correlator bank 22. In case a higher
quality grade was associated to the new search option
15   than to one of the search options currently processed in
one of the correlators of the supplementary correlator
bank 22, then the corresponding correlator of the
supplementary correlator bank 22 will stop processing the
previously assigned search option and start processing
20   the new search option.

The supplementary correlator bank 22 can be implemented
in various forms, three of which will be presented by way
of example in the following with reference to figures 4
25   to 9.

It is to be noted that the exact structure of the massive
correlator bank 21 is not of importance. The focus lies
on the distribution of tasks between the massive
30   correlator bank 21 and the supplementary correlator bank
22 and the structure of the supplementary correlator bank
22. Also different parallel solutions, concerning the
temporal and spatial dimensions, can be used to implement

the correlators in the massive correlator bank 21 and the
supplementary correlator bank 22.

Figure 4 is a schematic block diagram of a first
5   embodiment of a supplementary correlator bank 22 in the
structure of figure 2.

The supplementary correlator bank 22 of figure 4
comprises a plurality of correlators 41. In each
10   correlator 41, a sample input is connected via two
subsequent multiplication elements 42, 43 and a
multiplexer 44 to an integrating portion 45. Moreover, a
code-phase indication input is connected to an input of a
code generator 46. The output of the code generator 46 is
15   connected to the first multiplication element 42. In
addition, a frequency indication input is connected to an
input of a carrier generator 47. The output of the
carrier generator 47 is connected to the second
multiplication element 43. Finally, an integration result
20   input is connected to the multiplexer 44.

The operation of the supplementary correlator bank 22 of
figure 4 is illustrated in the flow chart of figure 5.

25   The supplementary correlator bank 22 assigns each search
option received from the massive correlator bank 21 to a
specific one of its correlators 41. The search option
comprises an indication of a specific code-phase τ_i, which
is fed to the code-phase indication input of the
30   respective correlator 41, and a specific frequency f_i,
which is fed to the frequency indication input of the
respective correlator 41. The result s_i of a coherent
integration associated to the search option is provided

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to the integration result input of the correlator 41. The integration result S_i is the result of a coherent integration at the massive correlator bank 21.

5   The code-phase indication τ_i is fed within the correlator 41 to the code generator 46, which generates a replica code sequence and aligns it according to the indicated code-phase. The received input samples are then multiplied by the first multiplication element 42
10   element-wise with the respectively aligned samples of the replica code sequence, as far as they have not been used already in the massive correlator bank 21.

The frequency indication f_i is fed within the correlator
15   41 to the carrier generator 47, which generates a corresponding sinusoidal signal. The second multiplication element 43 multiplies the samples output by the first multiplication element 42 element-wise with the sinusoidal signal generated by the carrier generator
20   47.

It is to be noted that the order of the two different multiplication operations by the first multiplication element 42 and the second multiplication element 43 can
25   also be reversed.

The output of the second multiplication element 43 and the result of the coherent integration S_i are provided via the multiplexer 44 to the integrating portion 45.
30
The integrating portion 45 integrates the multiplication results and includes in the integration as well the integration result S_i provided by the massive correlator

bank 21. The integration may consist in a coherent
accumulation, but it may include as well a non-coherent
accumulation, as described above as second alternative
for the integration in the massive correlator bank 21. If
5   the final integration result lies below a predetermined
threshold, the result is dumped. Otherwise, the final
integration result is provided to some processing means,
for instance to the DSP 15, for determining the best
correlation result for all search options. Then, the
10 correlator 41 is released for a refined correlation
based on the next search option.

Figure 6 is a schematic block diagram of a second ·
embodiment of a supplementary correlator bank 22 in the
15 structure of figure 2.

The supplementary correlator bank 21 of figure 6
comprises again a plurality of correlators 61, of which
only one is shown. In each correlator 61, a sample input
20 is connected via two subsequent multiplication elements
62, 63 to an integrating portion 64. The integrating
portion 64 is further connected via a portion 65 forming
absolute or square values of input values and via a
multiplexer 66 to a second integrating portion 67.
25 Further, a code-phase indication input is connected to an
input of a code generator 68. The output of the code
generator 68 is connected to the first multiplication
element 62. A frequency indication input is connected to
an input of a carrier generator 69. The output of the
30 carrier generator 69 is connected to the second
multiplication element 63. Finally, an integration result
input is connected to the multiplexer 66.

The operation of the supplementary correlator bank 22 of figure 6 is illustrated in the flow chart of figure 7.

The supplementary correlator bank 22 assigns each search
5   option received from the massive correlator bank 21 to a specific one of its correlators 61. The search option comprises an indication of a specific code-phase τ_i, which is fed to the code-phase indication input of the respective correlator 61, and a specific frequency f_i,
10 which is fed to the frequency indication input of the respective correlator 61. The result s_i of a coherent integration associated to the search option is provided to the integration result input of the respective correlator 61. The integration result S_i is the result of
15 a non-coherent integration at the massive correlator bank 21.

The code-phase indication τ_i and the frequency indication f_i are made use of by the code generator 68 and the
20 carrier generator 69 as described with reference to figure 4 for code generator 46 and the carrier generator 47, respectively. Also the output of the code generator and of the carrier generator is made use of in the multiplication elements 62, 63 as described with
25 reference to figure 4 for multiplication elements 42, 43, respectively.

The output of the second multiplication element 63 is provided to the integrating portion 64. The integrating
30 portion 64 integrates subsequent groups of multiplication results provided by the second multiplication element 63 separately. Portion 65 determines the square value or the absolute value of each integration result.

The square values or the absolute values, respectively, and the non-coherent integration result S_i provided by the massive correlator bank 21 are provided via the

5   multiplexer 66 to the second integrating portion 67. In the second integrating portion 67, the square values or the absolute values, respectively, are integrated in a non-coherent integration, the non-coherent integration result S_i of the massive correlator bank 21 being included

10   in this second integration.

If the final non-coherent integration result lies below a predetermined threshold, the result is dumped. Otherwise, the final non-coherent integration result is provided to

15   some processing means, for instance to the DSP 15, for determining the best correlation result for all search options. Then, the correlator 61 is released for a refined correlation based on the next search option.

20   Figure 8 is a schematic block diagram of a third embodiment of a supplementary correlator bank in the structure of figure 2.

The supplementary correlator bank 21 of figure 8

25   comprises again a plurality of correlators 81, of which only one is shown. In each correlator 81, a sample input is connected via two subsequent multiplication elements 82, 83 to an integrating portion 84. The integrating portion 84 is further connected via a portion 85 forming

30   absolute or square values of input values to a second integrating portion 86. Further, a code-phase indication input is connected to an input of a code generator 87. The output of the code generator 87 is connected to the first multiplication element 82. Moreover, a frequency

indication input is connected to an input of a carrier generator 88. The output of the carrier generator 88 is connected to the second multiplication element 83.

5   The second integrating portion 86 is connected via an output of the correlator 81 to the DSP 15 of the GPS receiver 12. Also the massive correlator bank 21 is connected to the DSP 15.

10   The operation of the supplementary correlator bank 22 of figure 8 is illustrated in the flow chart of figure 9.

The operation of the correlator 81 of the supplementary correlator bank 22 of figure 8 is the same as the
15   operation of the correlator 61 of the supplementary correlator bank 22 of figure 6, except that the second integrating portion 86 does not include any integration results from the massive correlator bank 21 in the non-coherent integration.
20

Non-coherent integration results S_i of the massive correlator bank for each search option are rather provided directly to the DSP 15.

25   The DSP 15 uses the non-coherent integration results S_i from the massive correlator bank 21 and from the supplementary correlator bank 22 in a multistage acquisition algorithm for the final signal acquisition. Such an algorithm has been described for example by
30   Kaplan.

Alternatively, the DSP 15 shown in figure 8 and in figure 1 could also be part of the mobile terminal 11 outside of the GPS receiver 12, or be implemented in the mobile

communication network 16. In the latter case, the integration results of the supplementary correlator bank 22 and, in the case of figure 8, of the massive correlator bank 21 are transmitted to the mobile

5 communication network 16 making use of the regular communication abilities of the mobile terminal 11.

In cases in which the mobile communication network 16 provides assistance data to the mobile terminal 11, the

10 search options may already be limited due to this assistance data, so that the entire acquisition may be performed by the supplementary correlator bank 22. Such assistance data may comprise for example information on the positions of the GPS satellites 19 and on a rough

15 position of the mobile terminal 11, which limits the possible code phases. The massive correlator bank 21 can then be switched off in order to reduce the power consumption.

20 While there have shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices and methods described

25 may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to

30 achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any

other disclosed or described or suggested form or
embodiment as a general matter of design choice. It is
the intention, therefore, to be limited only as indicated
by the scope of the claims appended hereto.